APPENDIX B

WATER QUALITY EVALUATION

WATER QUALITY EVALUATION

PREPARED BY

U.S. ENVIRONMENTAL PROTECTION AGENCY

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EXISTING INFORMATION

A. REVIEW OF EXISTING INFORMATION

1. Water Quality Monitoring Programs

a. U.S. Geological Survey (USGS)

The USGS has collected the largest amount of historical information on water quality in the LB area. Monitoring data are available for as far back as 1939 for approximately 140 surface and groundwater monitoring locations. Monitoring at the majority of the stations in the LB planning area ceased between about 1980 and 1985. This limits the use of these data to address recent water quality conditions. Parameters monitored at the remaining stations are limited to, at most, water level, chloride, and conductivity. USGS monitoring data are, therefore, of limited usefulness in assessing potential impacts of the proposed LB plan.

Historical monitoring results, contained in STORET, from USGS stations in the LB planning area indicate that a number of trace metals, organics, and bacteria were detected at canal and well stations. Surface and groundwater contained concentrations well above detection limits for a number of metals including aluminum, arsenic, boron, chromium, copper, iron, manganese, nickel, strontium, and zinc. Other metals present at concentrations near detection limits were cadmium, cobalt, lead, mercury, silver, and vanadium. Groundwater in the vicinity also contained detectable levels of phenols. Surface waters in the LB area contained detectable levels of bacteria that may pose a health threat. The bacteria monitored included fecal coliform and fecal streptococcus. Although no surface or groundwater contained detectable levels of hydrocarbons, canal sediments contained detectable levels of PCBs, DDE, DDD, 2,4-D, 2,4,5-T, dieldrin and silvex.

b. U.S. Environmental Protection Agency (USEPA

The USEPA monitoring locations are at point source discharges to the east of the proposed LB area and have been limited to sewage treatment plant influent and effluent locations. In addition, the data available for the area were collected prior to 1980. The value of these monitoring data for assessing impacts of the proposed LB Plan is, therefore, very limited.

c. Florida Department of Environmental Protection (FLDEP

FDEP's one groundwater location in the LB area has been monitored since 1990. FLDEP active surface water locations in the vicinity of the LB area consist of four canal locations.

Monitoring frequency at surface water canal locations varies with parameters and also with location. For the majority of stations, physical parameters of temperature, pH, conductivity, and dissolved oxygen are monitored quarterly and color is monitored annually. The only anion monitored in surface waters is chloride, which is monitored annually. Nutrients including total nitrogen, total Kjeldahl nitrogen, ammonia, nitrate, total phosphorous and total ortho-phosphorous are also monitored annually. Organics including organochlorine pesticides, PCBs, and chlorinated hydrocarbons are monitored biannually at three surface water locations. In addition, the monitoring program includes quarterly monitoring of biochemical oxygen demand and annual monitoring of bacterial contamination (e.g., total coliform, fecal coliform, and fecal streptococcus). Trace metals are monitored at one station in FLDEP's surface water monitoring program and include analysis for cadmium, copper, chromium, iron, lead, mercury, and zinc.

Averages for a number of parameters monitored and contained in STORET for active FLDEP surface stations in the LB planning area are summarized in Table 1. In addition to these parameters, monitoring results indicate detection of a number of trace metals, organics, and bacteria. Only one of the four canal stations (28042070) was monitored for trace metals. Iron, with an average concentration of 0.3 mg/L, was the only metal with concentrations well above detection limits. The station contained samples with concentrations near detection limits for a number of trace metals, including copper, lead, and zinc. However, the majority of sample results were less than detection limits. Cadmium and manganese were also found at concentrations above detection limits in some individual samples.

Table 1: Average Concentrations Reported in Storet for FLDEP Active Surface Water Quality Monitoring Stations[1]

		Cond.	D.O.		TKN	NH_4-N	NO_x-N	Total P	Cl
28040395	46.4	740	5.4	7.3	1.3	0.1	0.09	0.02	61
28040396	51	793	2.6	7.1	1.5	0.33	0.02	0.01	78
28040397	52	786	1.5	7	1.5	0.31	0.02	0.01	71
28042070	57	754	1.2	7	1.6	0.31	0.04	0.24	104

Abbreviations are as follows: Cond. = Conductivity; D.O. = Dissolved Oxygen; TKN = Total Kjeldahl Nitrogen; NH_4-N = Ammonia Nitrogen; NO_x-N = Nitrite/Nitrate Oxygen; P = Phosphorus; Cl = Chlorine; TOC = Total Organic Carbon.

Surface waters in the LB area also contained detectable levels of total coliform, fecal coliform, and fecal streptococcus bacteria, used as indicators of other bacteria that may pose a health threat. Levels ranged from 0 to 35,000 per mL for total coliform, 2 to 240 per mL for fecal coliform, and 2 to 18 per 100 mL for fecal streptococcus bacteria. The bacterial levels are not unexpected for surface water stations receiving runoff from surrounding agricultural and urban areas and inputs from a variety of wildlife. No detectable concentrations of hydrocarbons were found at the surface water station.

d. South Florida Water Management District (SFWMD

SFWMD monitors surface water at seven canal locations in the LB area, two of these canal locations are part of SFWMD's routine sampling program The two locations have been monitored since 1977 for a full-range of parameters including the following

- monthly monitoring of temperature, turbidity, color, pH, conductivity, dissolved oxygen, alkalinity, chloride, total nitrogen, organic nitrogen, ammonia, total Kjeldahl nitrogen, nitrate, nitrite, and total phosphorous,
- bimonthly monitoring of sulfate, calcium, magnesium, sodium, and potassium,
- quarterly monitoring of residue, ortho-phosphate, arsenic, cadmium, chromium, copper, iron, manganese, lead, strontium, mercury and zinc, and
- biannual monitoring of chlorinated pesticides, and PCBs

The historical results contained in STORET for a number of parameters monitored in the SFWMD program are summarized in Table 2 The results for the parameters in the table are similar to water quality results reported for FLDEP monitoring stations The iron concentrations are also similar to those at the FLDEP—0 3 mg/L Strontium was measured at 1 0 mg/L, well above detection limits In addition, several other trace metals monitored at the canal stations were detected in some samples, however, the majority of results were below detection limits for these parameters No chlorinated pesticides or PCBs were detected at the canal stations

Table 2 Average Concentrations Reported in STORET for SFWMD Active Surface Water Quality Monitoring Stations[1]

		Cond.	Alkal.	D.O.		TKN	NH_4-N	NO_x-N	Total P	TOC
S9	68	826	252	1.9	7.3	1.9	0.38	0.06	0.02	24
S151	75	805	208	3.5	7.1	1.9	0.06	0.15	0.03	25

For abbreviations, see note to Table 1

e. Broward County Office of Natural Resources Protection (ONRP

The Broward County ONRP conducts a countywide surface and groundwater quality monitoring program Within the vicinity of the LB area, two canal stations are monitored quarterly for a number of parameters The parameters include conductivity, pH, turbidity, temperature, dissolved oxygen, ammonia, nitrate, total nitrogen, total Kjeldahl nitrogen, organic nitrogen, total phosphorous, total organic carbon, biochemical oxygen demand, and bacteria (total coliform, fecal coliform, and fecal streptococcus) The groundwater monitoring includes three monitoring locations, all of which contain two wells of various groundwater depths Parameters monitored annually at the groundwater stations include the following

- physical parameters—conductivity, total dissolved solids, pH, Eh, temperature, and dissolved oxygen,
- nutrients—ammonia, nitrate, nitrite, and ortho-phosphorous,

- anions—alkalinity, chloride, fluoride, and sulfate,
- metals—aluminum, arsenic, barium, calcium, cadmium, chromium, copper, iron, lead, magnesium, manganese, potassium, sodium, and zinc, and,
- organics—dissolved organic carbon, purgeable aromatics and halocarbons, polynuclear aromatic halocarbons, and chlorinated hydrocarbons

Table 3 contains the averages for canal stations calculated from ONRP's routine monitoring results No trace metals or hydrocarbon results were reported for the canal stations Bacteria were detected at surface water stations in the following concentration ranges 0 to 1300 per mL for total coliform, 0 to 240 per mL for fecal coliform, and 0 to 640 bacteria per 100 mL for fecal streptococcus bacteria Groundwater monitoring data from ONRP were also used to calculate averages for parameters reported in Table 3 Detectable trace metals were reported for all groundwater water stations in the program Trace metals including aluminum, iron, and manganese were found at all locations and in nearly all samples at concentrations above detection limits The monitoring data also indicated arsenic, cadmium, chromium, nickel, lead, and zinc were detected, at concentrations near detection limits, in less than 70 percent of the groundwater samples None of the groundwater locations contained detectable concentrations of hydrocarbons analyzed

Table 3 Average Concentrations Reported in Monitoring Results Obtained from ONRPfor Active Surface and Groundwater Quality Monitoring Stations[1]

	Cond.	Alkal.	D.O.		TKN	NH_4-N	NO_X-N	Total P	TOC	Cl
31	709	NA	2.8	7.3	1.2	0.2	0.1	0.04	23	NA
32	740	NA	1 4	7 3	1 3	0 1	0 02	0 02	22	NA
G-2160	476	202	0 4	7 10	NA	0 57	0 07	0 01	11	23
G-2160A	329	156	0 4	7 30	NA	0 23	0	0 03	9 1	8 2
G-2369	676	272	0 2	6 80	NA	2 23	0	0 01	37	26
G-2369A	582	230	0 2	6 90	NA	0 92	2 32	0 01	32	27
G-2374	660	284	0 3	6 80	NA	1 16	0 01	0 01	24	31
G-2374A	590	266	0 3	6 90	NA	0 96	0 02	0 05	35	17

For abbreviations, see note to Table 1

f. Dade County Department of Environmental Resources Management (DERM)

DERM provides the most extensive monitoring within the LB area DERM maintains two separate monitoring programs, the Northwest Wellfield Monitoring Program and the West Wellfield Monitoring Program These correspond to two important public drinking water sources for a large number of Dade County residents The Northwest Wellfield is located in the center of the proposed LB plan and the West Wellfield is located in the southern portion of the LB area The monitoring stations surrounding the two wellfields are located within, and in close proximity to, the proposed LB Plan

The Northwest Wellfield Monitoring Program consists of three canal stations and twenty-six groundwater stations in and surrounding the Northwest Wellfield Two of the canal and six existing groundwater stations are located in the LB area, several groundwater stations in the LB area have been destroyed Five of the groundwater stations in the LB area are comprised of two monitoring wells screened to different depths in the Biscayne Aquifer Monitoring involves

- annual monitoring of ammonia, chlorides, total dissolved solids, trace metals, and phenols,
- biannual monitoring of purgeable halocarbons, purgeable aromatics, phthalates, major cations, and anions, and
- triannual monitoring of purgeable halocarbons and aromatics, organochlorine pesticides, PCBs, polynuclear aromatic hydrocarbons, chlorinated hydrocarbons, phthalates, nitrates, nitrites, and phosphorous

The West Wellfield Monitoring Program includes sampling at four canal stations and fourteen groundwater monitoring wells Three of the canal and six of the groundwater stations are located in the southern portion of the LB area Similar to the Northwest Wellfield program, several of the groundwater stations in the West Wellfield program contain two wells to allow for the sampling of two different groundwater depths Monitoring at West Wellfield monitoring stations includes the following

- quarterly monitoring of ammonia, nitrate, nitrite, total phosphorous, ortho-phosphorous, and total suspended solids,
- semi-annual monitoring of color and iron,
- annual monitoring of calcium, magnesium, sodium, potassium, sulfate, chloride, fluoride alkalinity, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, zinc, and total organic carbon, and
- triannual monitoring of purgeable halocarbons and aromatics, organochlorine pesticides, PCBs, phthalates, polynuclear aromatic hydrocarbons, and chlorinated hydrocarbons

Summaries of the Northwest Wellfield Monitoring Program were provided by DERM (see Tables 4 and 5) Trace metal results were not provided by DERM However, many of the stations were USGS stations, therefore, detectable trace metals should be similar to the historic USGS results reported above Discussions with DERM indicate that hydrocarbons monitored at the stations are below or at detection limits

Table 4 Average Concentrations Reported in Monitoring Results Obtained from DERM Northwest Wellfield Active Surface and Groundwater Quality Monitoring Stations[1]

	Cond.	D.O.	pH	TKN	NH_4-N	NO_x-N	Total	Color	Cl
SP-13	524	1.6	7.2	NA	0.17	0.02	0.007	67	65.4
SP-15	539	1 7	7 2	NA	0 14	0 04	0 008	43	67 6

NW-3A	896	1	6.90	NA	0.66	0.01	0.014	60	97.5
NW-3B	695	1	6.80	NA	0.7	0.01	0.007	65	87.2
NW-4A	699	0.3	7.30	NA	0.2	0.02	0.004	15	67.2
NW-4B	582	0.3	6.80	NA	0.76	0.06	0.011	60	68.9
NW-6A	505	0.3	6.50	NA	0.24	0.06	0.003	57	62
NW-6B	515	0.4	6.90	NA	0.3	0.02	0.004	56	60.5
NW-7A	525	0.2	6.90	NA	0.65	0.07	0.005	51	59
NW-7B	548	0.2	6.90	NA	0.41	<0.01	0.008	90	56.3
NW-8A	531	0.4	7.00	NA	0.65	<0.01	0.012	65	61
NW-8B	505	0.2	7.00	NA	0.56	0.02	0.009	68	63.8
NW-13A	542	1.4	6.90	NA	0.42	<0.01	<0.001	136	69.3
NW-13B	545	0.5	6.90	NA	0.3	<0.01	0.324	133	72.7
NW-15A	589	0.2	6.90	NA	0.92	0.04	0.007	64	44.9
NW-15B	657	0.2	6.80	NA	0.85	0.05	0.01	59	58.9

For abbreviations, see note to Table 1

Table 5 Average Concentrations Reported in Monitoring Results Obtained from DERM West Wellfield Active Surface and Groundwater Quality Monitoring Stations[1]

Station	TDS mg/L	Alkal. mg/L	D.O. mg/L	pH	TKN mg/L	NH_4-N mg/L	NO_x-N mg/L	Total P mg/L	TOC mg/L	Cl mg/L
LN00	398	199	1.2	7.3	1.4	0.41	0.03	0.01	21.3	75
LN01	369	196	1	7.3	1.6	0.36	0.02	0.02	19.5	85
BL12	367	210	1	7.30	1.2	0.33	0.03	0.01	20	72
WWF-01	366	256	0.2	7.1	2	1.25	0.01	0.02	22.1	59
WWF-02	383	227	0.2	7.1	1.9	0.77	0.05	0.01	24.8	69
WWF-07	316	182	0.2	7.3	0.8	0.08	0.05	0.02	14.3	66
WWF-09	370	219	0.2	7.2	1.4	0.38	0.05	0.01	23.4	72
WWF-10	379	219	0.2	7.1	0.8	0.08	0.25	0.02	14.5	62
WWF-12	397	245	0.2	7.0	1.1	0.21	1.94	0.02	11.5	57
WWF-15	342	224	0.2	7.1	1.7	0.75	0.27	0.02	21.4	63

For abbreviations, see note to Table 1

The data summary for the West Wellfield Monitoring Program includes trace metal but not hydrocarbon results The trace metal results indicate that arsenic, iron, manganese, lead, and zinc are found at levels well above detection limits at one or several monitoring locations Chromium and copper were also detected, but at levels near or at the detection limits DERM personnel indicate that hydrocarbons monitored at the West Wellfield locations are below or at detection limits Results for the other parameters are shown in Table 5

2. Other Water Quality Studies

a. Borrow Pits

Water quality data for borrow pits in the LB area is limited to only five borrow pits and is somewhat dated (i e , greater than 10 years old) The water quality results are summarized in Tables 6 and 7 Tessier and Amy (1977) analyzed water from three borrow pits in Dade County in a study of the effects of mining activities on surrounding groundwater quality Hudy and Gregory (1984) examined limnological characteristics of eight limestone excavations in South Florida, however, only two of the excavations are located in the LB region

Table 6 Concentrations Reported in Tessier and Amy (1977) for Three Borrow Pits Located in the Lake Belt Area

Station	TDS mg/L	Alkal. mg/L	Hard. mg/L	SO_4^{-2} mg/L	TON mg/L	NH_4-N mg/L	NO_x-N mg/L	Total P mg/L	COD mg/L	Cl mg/L
Pit 7	346	164	185	11 2	1 5	0 35	0 29	0 08	52	31
Pit 9	448	232	253	25 3	2	0 44	0 37	0 07	94	55
Pit 10	428	240	261	85 8	2	0 44	0 33	0 18	60	53

For abbreviations, see note to Table 1

Table 7 Average Concentrations Reported in Hudy and Gregory (1984) for Several Borrow Pits Located in the Lake Belt Area

Station	Cond. mho's	Alkal. mg/L	D.O. mg/L	pH	Total N mg/L	Total P mg/L	Hardness mg/L	chlorophyll a g/L
Lake 2	477	170	7 5	7 7	0 9	0 007	188	2 4
Lake 3	412	129	7 5	7 6	0 7	0 009	147	1 2

For abbreviations, see note to Table 1

Another study by Tessier and Amy (1978) measured a number of trace metals (i e , aluminum, copper, iron, lead, nickel, zinc, mercury, and strontium) and found copper concentrations ranging from 0 26 to 0 81 mg/L, well above current water quality standards All other trace metals in the borrow pits were at non-detectable concentrations, or at concentrations well below current water quality standards

Hudy and Gregory (1984) was the only study available that collected and analyzed sediments in borrow pits from the LB area for metals The metals determined from the two borrow pits in the LB area are summarized in Table 8 The majority of the trace metals (i e , As, Cr, Cu, Pb, Zn) in the sediments are at low concentrations This indicates that the sediments were not previously contaminated from mining activities or from the precipitation of metals from the water column

Table 8 Sediment Concentrations (in mg/kg) Reported in Hudy and Gregory (1984) for Two Borrow Pits Located in the Lake Belt Area

Station	TOC	As	Ca	Cr	Cu	Fe	Pb	Mn	K	Sr	Zn
Lake 2	5400	2 4	345000	7 4	2 7	3319	12 6	48 1	18012	868	4 7
Lake 3	3400	2 5	398756	0 9	3 9	1906	7 7	33 8	15912	791	3

For abbreviations, see note to Table 1

Using hydrogeologic analysis and illustration, Hydrologic Associates (no date) concluded that rock mining to a depth of 55 feet compared to 40 feet would not cause any greater impact on surrounding groundwater quality They attribute this result to the fact that the flow to and from the pits was horizontally through side slopes, and not vertically through the bottom Tessier and Amy (1978) investigated water quality in three borrow pits and nearby wells, and found no significant differences in water quality, they concluded that the pits pose no threat to the quality of water in the Biscayne Aquifer as long as the areas around the pits remain vegetated and undeveloped

Beaven and McPherson (1978) sampled one rock-pit in Broward County during an investigation to evaluate impacts of highway runoff on pit water quality, but this pit was not located within the LB area In two studies, Jackson and Maurrasse (1976a and 1976b) surveyed water quality of developed rock-mined pits and real estate lakes in Dade County and found the majority of lakes to be greatly influenced by elevated nutrient loading from residential runoff and discharges to lakes Weinberg et al (1980) found that urban runoff from a high density residential level (multi-family units) to a man-made lake (rock-pit) did not degrade groundwater quality Hudy and Gregory (1984) characterized abiotic and biotic aspects of water-filled limestone excavations (limnology, macroinvertebrates, fisheries, and contaminants in lake sediments) and found no evidence of gross contamination of heavy metals or pesticides in bottom sediments They did conclude that eutrophication may occur in urban areas Burney and Forman (1991), investigating a deep lime-rock pit that received treated wastewater and suburban stormwater for 20 years, found pit water quality to be unaffected by wastewater inputs and found that the borrow pits effectively remove nutrients and trace metals from groundwater and surface water inputs

b. Wetlands

No studies were found on the effects of limestone mining and borrow pits on water quality in adjacent wetlands This lack of studies is to be expected because high permeability of the soils and underlying aquifer preclude the discharge of water from the borrow pits and/or limestone mining to adjacent wetlands

One study was identified that examined the effect that nearby Everglade wetlands have on water quality of the Biscayne Aquifer Parsons and Pruitt (1992) conducted a study that found Everglades peat to be important in toxicant removal/retention and nutrient retention In general, wetlands' effect on the quality of underlying groundwater have been attributed to the following processes

- reduction in water velocity in wetlands,
- precipitation of metals and decomposition of hydrocarbons by a variety of anaerobic and aerobic processes,
- high productivity rates in phytoplankton and macrophytes that can result in high mineral uptake rates,
- chemical transformation from the diversity of decomposers and decomposition processes,
- adsorption and absorption of agents from the high water-to-surface area contact, and
- large stable sinks within the organic (peat) layer

c. Canals

As discussed previously, a well-established network of canal stations are monitored in the LB area under four state and county programs In addition to routine monitoring, Sonntag (1980) evaluated water quality in canals in Broward County, Florida, for an extended period from 1975 and 1978 as part of a study to evaluate the potential impact of wastewater and storm runoff to groundwater quality

No information was identified that evaluated the effects of limestone mining and borrow pits on surface waters (canals) in proximity to borrow pits

A study by Miller (1978) examined the effects that bottom sediments in canals have on infiltration to the Biscayne Aquifer The study suggests that bottom sediments reduce the concentrations of some constituents in the infiltrating water, and that consequently removal of the canal bottom sediments may increase infiltration, but at the expense of reduced water quality in the Biscayne Aquifer Chin (1991), in a study of leakage from clogged channels that partially penetrate surficial aquifers, found groundwater recharge to be affected by sediment permeability Meyer (1972) evaluated the effects that canal systems (Miami Canal System) have on recharge of the Biscayne Aquifer in the vicinity of a public water supply and found infiltration rates to increase in response to higher pump rates

d. Groundwater

Groundwater quality has also been assessed in a number of investigations SFWMD (1992), in a background document assessing future water uses and supply sources, compiled a summary of water quality data from their groundwater monitoring network that included stations within the study area Radell and Katz (1991) evaluated major ions and selected trace metal chemistry of the Biscayne Aquifer in southeast Florida, from monitoring data collected by SFWMD from August 1984 through January 1989 and the USGS from October 1975 through October 1989 Herr and Shaw (1989) evaluated groundwater quality of several key parameters (e g , chloride, calcium) at

SFWMD and DERM groundwater quality monitoring stations Sonntag (1987) determined the vertical and horizontal distribution of water quality characteristics of the surficial aquifer in Dade County Waller and Cannon (1986) conducted a groundwater quality investigation at a network of monitoring wells in eastern Broward County, Florida, from 1983 to 1984 that includes between 10 and 14 stations in the study area A summary by Klein and Hull (1978) evaluated existing groundwater quality of the Biscayne Aquifer by reviewing information contained in local, state, and federal reports and files They also evaluated untreated water from selected municipal wellfields and two everglades test wells, water from selected canals, and runoff from low- and high-density residential areas

In addition to water quality data, a number of available documents contain information on the stratigraphy, geology, and mineralogy of the Biscayne Aquifer Fish and Stewart (1991) define the hydraulic conductivities and thicknesses of the various stratigraphic units of the Biscayne Aquifer in Dade County Meyer (1988 and 1989) evaluated the hydrogeology and subsurface storage of the non-potable Floridan Aquifer, which lies beneath the potable Biscayne Aquifer

A number of documents also discuss the Biscayne Aquifer with respect to its hydrogeologic characteristics and potential of contamination Klein and Hull (1978) summarized geologic, hydrologic, water quality, and other information related to the Biscayne Aquifer to assist the USEPA in its decision regarding designation of the Biscayne Aquifer as a sole-source aquifer James M Montgomery Engineers (1986) conducted a study of water supply in Broward County, Florida, and identified future locations of water supply wells that would not be affected by salt water intrusion, contamination, or total organic carbon

Several studies investigated the impacts of limestone mining and borrow pits on groundwater quality Burney and Forman (1991) analyzed groundwater quality at monitoring wells above and below gradient of a borrow pit that received wastewater treatment effluent The results indicated the borrow pit removed nutrients and trace metals from the effluent and influent groundwater Tessier and Amy (1978) investigated groundwater impacts at borrow pits by installing monitoring wells adjacent to three pits No significant differences in water quality were noted between the three sets of samples and nearby USGS observation wells, and potable water standards were not exceeded for any nutrients or heavy metals

3. Studies Relating to Water Quality Processes

a. Limnological Processes

Eutrophication is the natural aging process within lake systems Cultural eutrophication is the accelerated aging of lakes in response to excessive nutrient additions from human sources In many cases this accelerated aging has serious impacts on water quality by depleting dissolved oxygen and producing toxic sulfides, which can result in fish kills In addition, cultural eutrophication can produce unsightly nuisance algal and plant growth and excessive odors from the decay of organic material Nutrient concentrations and measures of productivity (e g , chlorophyll a) are indicators of the trophic state of lake systems

Nutrient concentrations in borrow pits were examined by several investigators Burney and Forman (1991) measured total nitrogen and phosphorous concentrations of approximately 1 mg/L and 0 1 mg/L, respectively, in borrow pits receiving treated effluent with concentrations in excess of 10 mg/L and 5 mg/L, respectively Hudy and Gregory (1984) measured nutrient concentrations in eight different borrow pits and found total nitrogen to range from 0 2 to 1 0 mg/L and total phosphorous to range from 0 004 to 0 018 mg/L Tessier and Amy (1978), in a study of three borrow pits in Dade County, measured total nitrogen of between 2 and 3 mg/L and total phosphorous between 0 07 and 0 18 mg/L The concentrations measured exceed levels identified as potentially causing nuisance growth of algae 0 3 mg/L inorganic nitrogen and 0 01 mg/L phosphorous (Sawyer 1966)

Borrow pit productivity was examined by several investigators Burney and Forman (1991) found low net production (25 grams C/m^2/year) throughout the borrow pits, even with the high input of nutrients from the sewage treatment plant (STP) Hudy and Gregory (1984) measured chlorophyll a in borrow pits from 0 5 to 4 2 mg/m^3 These levels place the lakes in low productivity oligotrophic to oligo-mesotrophic classification, based on a system provided by Carlson (1977) The study also found low numbers and species diversity of fish and macroinvertebrates, further demonstrating the low productivity of the monitored lakes The low productivity in the lakes despite the elevated nutrient levels indicates that lake productivity may be controlled by some other factor Burney and Forman (1991) suggest that the low productivity may be due to high (saturated) calcium concentrations, which continually removes phytoplankton from surface waters as calcite ($CaCO_3$) precipitates and settles to the bottom sediments This process is further examined in the next section, on biogeochemical processes

Jackson (1976) evaluated residential lakes in the Dade County area, none of which were in the LB area, and found the majority to be affected by cultural eutrophication The lakes received excessive nutrient loading from septic systems, STP effluent, and stormwater runoff from fertilized lawns and agricultural areas The study suggests lake water quality in this region may be influenced by nutrient loading and result in cultural eutrophication However, many of the lakes monitored in this study were smaller (less than 1 acre), shallower (less than 25 feet), and within more heavily populated areas than typical lakes in the LB area

b. Biogeochemical Processes

Depending on dissolved oxygen levels, biogeochemical processes in the limestone pits can either eliminate toxic substances and nutrients from the water column through precipitation reactions or can cause the release of toxics and nutrients from lake sediments A number of studies investigated water quality and removal of metals and nutrients in borrow pits of South Florida
Geochemistry investigations of "marl" lakes are also relevant because, like borrow pits, these naturally-occurring lakes receive groundwater inputs from limestone aquifers

1. Nutrient Removal/Cycling

Lake productivity is a function of nutrient inputs to the system and their removal and cycling within the lake A number of studies at South Florida borrow pits have examined nutrient levels and inputs in borrow pits and the effect of inputs on productivity and water quality concerns, such as eutrophication

Burney and Forman (1991) evaluated conditions in a deep (45 feet) borrow pit, which received nutrient rich effluent from a wastewater treatment plant for over 20 years Nutrient (i e , nitrogen and phosphorous) concentrations in the effluent (10 mg/L total nitrogen and 5 mg/L total phosphorous) decreased rapidly within the borrow pit, while nutrient concentrations in sediments increased The study suggested that water chemistry (i e , high calcium concentration) of the borrow pit removed nutrients through precipitation as calcium minerals and through settling of phytoplankton from the epilimnion (surface waters) Low dissolved oxygen levels at depths greater than 25 feet also indicates that poor mixing within the borrow pit may have had an effect on biological activity and cycling of nutrients between sediments and surface waters This poor mixing was also supported in borrow pit depth profile data from Hudy and Gregory (1984), which contained low dissolved oxygen in hypolimnions (deep waters) where borrow pit depths exceeded 40 feet

No information was available to evaluate the biological activity in the borrow pit sediments, stability of nutrients accumulated in sediments, or the release of nutrients from sediments to overlying water The stability of nutrient deposits in sediments can be inferred from the absence of seasonal nutrient concentration fluctuations in surface waters in the borrow pits studied by Hudy and Gregory (1984) and Burney and Forman (1991) In addition, the absence of long-term changes during the 20 years of nutrient inputs to the borrow pit studied also suggests that nutrient release from anoxic sediments is minimal, possibly due to the calcareous nature of the sediment deposits Phosphorous, a limiting freshwater nutrient, is not easily released from calcium mineral deposits

A number of studies on "marl" lakes have examined the effects of nutrients on lake productivity and the fate of nutrients within the lakes Brown et al (1992) determined that the source of calcium in marl lakes is groundwater and that approximately 50 percent of this calcium influx is precipitated prior to outflow

Precipitation occurred directly in the water column forming calcite and indirectly during biological formation of aragonite in the form of mollusk shells The formation of calcite directly in the water column from supersaturated groundwater can cause water quality changes such as nutrient and trace metal removal The effects of the precipitation processes on lake productivity were studied by Hooper and Ball (1964), who found fertilization of marl lakes to be ineffective at increasing productivity due to the loss of phosphorus to the bottom muds as calcium deposits Duston et al (1978) analyzed water and sediments in a marl lake and determined that physiochemical and biochemical calcite precipitation processes are interrelated, producing the carbonate sediments in marl lakes Seasonal changes in calcite precipitation were observed These changes are due to lower carbon dioxide levels associated with elevated summer temperatures and phytoplankton and macrophyte productivity The investigators noted that most calcite precipitation formed as encrustations directly around phyoplankyon and macrophytes, which may decrease buoyancy and effectively remove phytoplankton from the epilimnion, thereby maintaining low lake productivity

2. Toxics Sequestering

Toxic substances released into surface and groundwater can be sequestered by precipitation, absorption, and adsorption A number of investigators examined borrow pit water quality and sediments to evaluate the ability of these systems to remove toxic substances

Burney and Forman (1991) examined sediments in two borrow pits receiving treated sewage treatment plant effluent and residential runoff for over 20 years The concentrations of heavy metals (i e , iron, zinc, manganese, copper, lead, and chromium) found in surficial layers of the sediment were found to be elevated in comparison to the concentrations in deeper sediments, which suggests that the borrow pits provide removal of heavy metals through precipitation and settling of suspended solids Weinberg et al (1980) investigated the effects of urban runoff on a man-made lake and found enriched levels of chloride, COD, TKN, and dissolved solids in lake waters and elevated levels of lead in sediments Down-gradient groundwater was lower in concentrations for all parameters, indicating that removal of pollutants in stormwater runoff occurred in the lake and/or adjacent rock material Beavin and McPherson (1978) examined several small lakes in the vicinity of a highway interchange and found elevated concentrations of chromium and lead in lake sediments, but no increases in surrounding groundwater concentrations These results also suggest that the lakes and/or adjacent rock material removed the metals from highway runoff

Several other studies investigated the importance of metal sequestering in canal sediments and wetland soils Miller (1978) found that sediments of canals were important in removing pollutants from water infiltrating into the underlying aquifer, which was based on differences in canal and adjacent groundwater However, the overall importance could not be determined due to the ameliorating effects of underlying material in the aquifer Parsons and Pruitt (1992) evaluated metal sequestering of wetland soils and found the soils to contain elevated concentrations of lead, zinc, and copper However, the experiment did not ascertain the overall benefit or detriment of the soils on metal retention and groundwater quality

c. Physical Processes

The response of borrow pits to precipitation and the interaction between groundwater flow and outflow from canals may be of importance in predicting borrow pit water quality and susceptibility of borrow pits to contamination Several investigations examined infiltration and permeability of lake and canal walls and bottoms Weinberg and Allman (1980) studied a man-made lake that received urban stormwater runoff They determined the lake to be a source of water to the surrounding aquifer during dry seasons while the aquifer supplied water to the borrow pits during certain high water table periods associated with wet seasons Miller (1978) examined how fine-grained sediments that accumulate on canal bottoms can greatly reduce infiltration to groundwater, thereby reducing the canals' contribution to wellfield recharge Deevey (1988) estimated downward leakage (deep-seepage outflow) and water level fluctuations from 20 lakes located in north, central, and South Florida

d. Geology and Mineralogy

Water quality of groundwater and surface water is often an expression of surrounding geology and mineralogy Man-made disturbances of the geology, through activities such as mining, can impact both groundwater and surface water quality Historic unregulated mining of coal in the Appalachian states is a well-documented illustration of the potential for geologic disturbances to degrade thousands of miles of streams and impart undrinkable qualities to large areas of groundwater

The LB planning area is located within the Biscayne Aquifer This aquifer has been well studied because of the use of this high-yield resource as a public water supply The most extensive evaluation of the Biscayne Aquifer in Dade and Broward counties was conducted by Causaras (1987) Causaras (1987) examined the Biscayne Aquifer lithology and determined the aquifer to be comprised of a number of discreet layers, all of which were comprised of various forms of limestone and sandstone Only qualitative reference to minor mineral compositions was provided

Klein and Hull (1978) examined the water quality of the Biscayne Aquifer on a regional basis and included an overview of implications of salt water intrusion, wastewater disposal, solid waste disposal, and agricultural and urban runoff on degradation of public water supplies Radell and Katz (1991) provided an extensive evaluation of Biscayne Aquifer water quality through examination of a data compilation from existing monitoring programs They indicate that the predominate water types within the LB planning area are derived from parental rock material and are comprised of the calcium-bicarbonate category Their trace metal evaluation found barium, chromium, copper, iron, manganese, and lead at detectable levels in greater than 50 percent of groundwater samples Iron was the only detected trace metal consistently present at concentrations above USEPA drinking water standards The investigators suggest that the source of the trace metals are leaching of iron and manganese from overlying soil and rock material, solubilization of barium from limestone minerals containing trace amounts of barium, atmospheric deposition of lead that is transported as a chelate with total organic carbon, and local contamination of copper and chromium from industry, agriculture, and urban runoff

No information evaluating the mineral composition of the Biscayne Aquifer was found However, the likelihood of potential impacts from surrounding mineralogy can be inferred The carbonate nature of the majority of strata within the Biscayne Aquifer will not likely contain mineralogy that can contribute to the degradation of water quality to greater degrees than has been observed in groundwater monitoring studies In addition, if mineralogic characteristics were such that mining would result in water quality degradation, this phenomenon would likely have been previously identified because of the long-term historical mining in South Florida within the Biscayne Aquifer

B. Lake Belt Water Quality Inventory

A water quality sampling program was designed and conducted to evaluate existing water quality in the LB area and assist in evaluating potential impacts of the proposed "Lake Belt Plan " The sampling program utilized existing groundwater and canal stations contained in previously discussed monitoring programs administered by DERM DERM stations were utilized for the following reasons the stations provide reasonably good coverage throughout the area, using one agency's stations lends consistency to the sampling program, and the agency's generously contributed field sampling efforts for the study The locations of sampling stations, frequency of sampling, parameters to be analyzed, quality assurance and control procedures, and coordination with existing programs are described below

1. Sampling Locations

Borrow pit (and sediment), groundwater, and canal sampling stations were included in the water quality sampling program The following sections summarize the stations selected for the water quality and geochemical process sampling programs

a. Borrow Pits

Approximately 50 borrow pits are located within the LB area However, not all borrow pits could be practically sampled as part of the inventory program A subsample of the existing borrow pits was selected with consideration of the following characteristics

- a north-south and east-west coverage within LB area,
- proximity and direction to existing groundwater monitoring stations with respect to expected groundwater flow,
- proximity and direction to an existing canal monitoring station,

- borrow pit morphology,
- land use in the vicinity and surrounding the borrow pit,
- differing levels of mitigation (e g , littoral wetlands and sloping sides), and
- inclusion of historically monitored borrow pits

Based on the above criteria, ten borrow pits were selected for sampling in the water quality inventory program Borrow pit sampling locations are summarized in Table 9 Four of the ten borrow pits selected for water quality sampling also included sediment sampling The program covered the full north-to-south and east-to-west range of borrow pits in the LB planning area Borrow pit ages, based on the permit files, cover the period from 1979 to 1991 Surface areas of included borrow pits range from 10 to 500 acres and depths range from 40 to 80 feet The borrow pits selected are surrounded by various land uses including wetland, urban, roadway, agriculture, and rangeland In an effort to cover the full range of expected mining techniques found in the LB, eight companies are represented in the sampling program Two borrow pits—Pits 9 and 10, sampled by Tessier and Amy (1978)—were included in the sampling program to evaluate any changes in water quality over time

Table 9 Borrow Pit Sampling Locations to Provide Water Quality Inventory and Evaluate Geochemical Processes in the Lake Belt Planning Area

Permit Number	Lake #	Permit Year	Area (Ac)	Depth (ft)	Mitigation	Company	Status
88IPO-20825[1]	1	1988	208	57	littoral shelf	White Rock	Active
87IPG-20364[1]	3	1987	330	56	littoral shelf	Rinker Materials Corp.	Active[5]
89IPO-20375	7	1990	186	63	littoral shelf	Tarmac America Inc.	Active
1984006142	6	1995	170	55	littoral shelf	Tarmac America Inc.	Inactive[3]
78P-1783	8	1988	144	38	littoral shelf	Union Rock	Active
1992004892	10	1994	118	39	littoral shelf	Florida Rock Industries	Active
199200489	9	1994	91	34	littoral shelf	Florida Rock Industries	Inactive[4]
87IPG-20305[1]	5	1987	253	36	littoral shelf	Rinker Materials Corp.	Active[5]
Upland	4	NA	121	29	None	Rinker Materials Corp.	Inactive[3]
90IPQ-03210[1]	11	1991	95	58	littoral shelf	Vulcan Materials	Inactive[4]

1 - Borrow pits to be sampled by EPA - Environmental Services Division for sediments
2 - Borrow pit location were QA/QC water quality samples were collected
3 - Excavation completed more than one year prior to sampling
4 - Excavation not complete but inactive at time of sampling
5 - Excavation completed in 1996 but active at time of sampling

b. Canal Stations

Canal sampling stations were selected to provide adequate surficial coverage of canal water quality in the LB planning area, and based on sampling canal stations that are in close proximity to borrow pit sampling locations The proposed canal stations are summarized in Table 10 All five of the canal stations are part of DERM's Northwest and West Wellfield Monitoring Programs

Table 10 Canal Sampling Locations to Inventory Water Quality and Address Geochemical Processes in the Lake Belt Planning Area

Station	Location		Surrounding Land Use	WQ Protection Program	Agency
	Longitude	Latitude			
MR15	80 25 48 00	25 55 58 00	wetlands agriculture	NW Wellfield	DERM
SP18	80 25 14 00	25 53 20 00	wetlands borrow pits	NW Wellfield	DERM
SP15	80 23 17 00	25 50 20 00	wetland	NW Wellfield	DERM
SP13	80 23 02 00	25 47 45.00	agriculture urban roadway	NW Wellfield	DERM
LN01	80 29 52 50	25 45 45 50	wetlands	West Wellfield	DERM

The five canal sampling stations should provide adequate assessment of canal water quality in the area The canal stations include the full range of north-to-south and east-to-west canal directions Several canal sampling locations are located on canals that are in close proximity to borrow pits in order to evaluate any water quality relationships between the two surface waters

c. Groundwater Stations

Groundwater stations were selected from existing monitoring wells in active programs because the status of historic wells could not be determined and no new wells can be constructed within the time frame of this study The seven well stations selected for sampling, summarized on Table 11, are from two wellfield monitoring programs administered by DERM, the Northwest, and West Wellfield Programs No other monitoring program contained active monitoring wells in the LB planning area Six of the seven well stations include two monitoring wells at different depths in the aquifer, which results in a total of thirteen wells in the sampling program

Table 11 Groundwater Sampling Locations to Inventory Water Quality and Address Geochemical Processes in the Lake Belt Planning Area

Station	Location		Depth (ft)	Land Use	WQ Protection Program	Agency
	Longitude	Latitude				
NW-3A	80 26 08 00	25 52 47 00	88	wetlands	NW Wellfield	DERM
NW-3B	80 26 08 00	25 52 47 00	26	wetlands	NW Wellfield	DERM
NW-15A	80 24 15 00	25 52 36 00	51	borrow pits	NW Wellfield	DERM
NW-15B	80 24 15 00	25 52 36 00	21	borrow pits	NW Wellfield	DERM
NW-8A	80 23 39 00	25 50 25 00	60	wetland/roadway	NW Wellfield	DERM
NW-8B	80 23 39 00	25 50 25 00	25	wetland/roadway	NW Wellfield	DERM
NW-9A	80 21 23 00	25 51 17 00	45	urban	NW Wellfield	DERM
NW-9B	80 21 23 00	25 51 17 00	23	urban	NW Wellfield	DERM
NW-47A	80 22 01 00	25 50 26 00	20	urban	NW Wellfield	DERM
NW-47B	80 22 01 00	25 50 26 00	54	urban	NW Wellfield	DERM
WWF-10	80 27 41 00	25 41 55 00	25	agriculture	West Wellfield	DERM

The monitoring well locations were selected to collect background water quality and water quality in close proximity to several borrow pits Background wells are located in wetland, agriculture, and urban land use types throughout the LB planning area, except the northern section In addition, a number of wells are located in close proximity to borrow pits in both up- gradient and down-gradient groundwater flow locations

2. Sampling Procedures

Each of the borrow pit, canal, and groundwater stations identified above were sampled twice during the program, once in April/May 1995 and once in February 1996 Sediment sampling at the four borrow pits was conducted only once, during the

April/May 1995 sampling round Sampling procedures for groundwater, canal and borrow pit, and sediment locations are summarized in the following paragraphs

Borrow pits included in the sampling program were sampled by Glenn Hohmeier of Larson and Associates with Gerald Miller as a representative from EPA Each borrow pit was sampled at the approximate center of the pit Sampling included in situ depth profile analysis and surface and bottom water collection for laboratory analysis Depth profiles included measurement of temperature, dissolved oxygen, conductivity, pH, and Eh at one meter intervals using a Hydrolab combination electrode A surface and a bottom water sample were collected for laboratory analysis from each borrow pit using either a van Dorn or Kemmerer type sampler

Four borrow pit stations, identified in Table 9, were sampled for sediments by EPA personnel, as part of the EPA's ongoing study, "Ecological Risk Assessment of Mercury Contamination in the Everglades " Surface and bottom water samples were also collected from the four borrow pits at the time the sediment samples were collected The sediment samples were collected at the approximate center of the borrow pits using a grab sampler The collected sediment cores were homogenized in a glass pan and placed in Teflon-lined glass containers Collected samples were chilled to 4^{o} C and delivered to the laboratory within 24 hours of sample collection

Groundwater stations were sampled by DERM according to sampling procedures outlined in their Quality Assurance Plan In general, the procedures require purging of three to five well volumes prior to sample collection to ensure samples are representative of groundwater in the aquifer After purging groundwater samples were collected in teflon bailers, transferred to polyethylene bottles, chilled to 4^{o} C, and transported to the laboratory within 24 hours

Canal stations were sampled by DERM according to sampling procedures outlined in their Quality Assurance Plan In general, samples were collected at midchannel, approximately 0 5 meter below the surface Canal sampling locations were selected to prevent influence and contamination from local structures such as bridges and flow control gates Field measurement of temperature, dissolved oxygen, conductivity, and pH were conducted at each location Canal samples were stored in polyethylene bottles, chilled to 4^{o} C, and transported to the laboratory within 24 hours

3. Sample Handling and Analysis

All water and sediment samples were chilled to 4^{o} C and delivered to the laboratory within 24 hours of sample collection Parameters analyzed on collected samples are summarized into three categories (metals, nonmetal inorganics, and organics) on Table 12 Parameters analyzed were selected based on their inclusion in existing sampling programs, historically detected at sampling locations in the vicinity of the LB Plan, and potential human health and ecological consequences of the parameter All analyses followed EPA procedures and protocols for laboratory analysis of water and sediment samples With the exception of the four borrow pits sampled, borrow pit, canal and groundwater samples were analyzed at an EPA contractor's laboratory Sediment samples and the borrow pit samples collected by EPA as part of the ESD sampling program were analyzed by the Environmental Services Division of EPA (EPA-ESD), located in Athens, Georgia

a. Sampling Program Results

1. Borrow Pits

Borrow pit sampling included the following components in situ depth profile sampling, and surface and bottom water quality sample However, bottom sediment sampling was only conducted during the first sampling round

a) In situ Depth Profiles

Depth profiles conducted in the borrow pits at the time of the water quality sampling are presented for each parameter measured (i e , temperature, pH, dissolved oxygen, conductivity, and Eh) in Attachment A The depth profiles from the April/May 1995 sampling differed from the depth profiles measured in the borrow pits during the February 1996 sampling The differences will be discussed here

During the April/May 1995 sampling, the borrow pits contained high surface water temperatures, ranging between 28 and 32 C Temperatures in the borrow pits were observed to decrease with depth in the majority of borrow pits, suggesting that the borrow pits were developing thermoclines Thermocline development, an important limnological process occurring during the warmer seasons, is the isolation of bottom waters from mixing and aeration The lower dissolved oxygen concentrations in the deeper waters of the borrow pits are a direct result of the development of thermoclines If anoxic (i e , lack of oxygen) conditions develop and prevail in the borrow pits for extended lengths of time during the growing season, thermoclines may affect biogeochemical cycling of nutrients and trace metals in the borrow pits Influence of the thermocline on biogeochemical processes in the majority of borrow pits during the April/May 1995 sampling is also suggested by the decrease of dissolved oxygen, increasing conductivity (a measure of total dissolved solids), and decreasing pH below the thermoclines

Temperatures during the February sampling were relatively constant throughout the borrow pit depths, ranging between 18 and 20 C Likewise, conductivity, dissolved oxygen, and pH were also found to vary little with depth in the borrow pits These results reflect a well-mixed condition in the borrow pits This is probably the result of the high precipitation and cooler air temperatures, which occurred prior to this sampling round

Table 12 Laboratory Analysis Performed on Water and Sediment Samples Collected for the Lake Belt Water Quality Inventory

Parameter	Borrow Pits	Canals	Groundwater	Sediments
Metal Inorganics				
Aluminum, Arsenic, Boron, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Nickel, Potassium, Sodium, Strontium, Zinc	•	•	•	•
Antimony, Barium, Beryllium, Cobalt, Molybdenum, Selenium, Tellurium, Thallium, Tin, Titanium, Vanadium, Ziconium	•1			•
Methyl Mercury	•1			•
Non-metal Inorganics				
pH, Alkalinity, Ammonia, Sulfate	•	•	•	•
Nitrate, Nitrite, Total Nitrogen, Total Phosphorous, Ortho-Phosphorous, Chloride, Fluoride	•	•	•	•
Sulfide				•
Organics				
Total Organic Carbon	•	•	•	•
Pesticides				•
PCBs				•
Purgeable Organics				•
chlorophyll a	•	•		

Analysis performed only on the four borrow pits sampled for sediments

b) Water Quality Samples

Borrow pits were sampled for a number of water quality parameters Attachment B contains the water quality results from samples collected at the ten borrow pits during the two sampling periods Comparison of results for the two sampling rounds indicates that water quality was similar in the borrow pits during the two sampling periods With some exceptions, the results from this sampling program are consistent with results reported by Hudy and Gregory (1984) and Tessier and Amy (1978) and described in section B 2 a

In general, borrow pits were well-buffered with alkalinities in excess of 100 mg/L, resulting in pH between 8 and 8 5 Nutrient (i e , nitrogen and phosphorous) levels in the borrow pits were at or below detection limits Low nutrient levels probably contributed to the low productivity of the borrow pits, as indicated by the low measured chlorophyl a concentrations

Borrow pit samples were analyzed for a number of trace metals the results are contained in Attachment C Trace metals were typically not detected in the borrow pit samples Trace metals not detected include antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, silver, tellurium, thallium, tin, titanium, vanadium, and zinc In contrast, Tessier and Amy (1978) reported levels of copper concentrations greater than 1 0 mg/L in the borrow pits they sampled The differences could be due to historic analytical error or to use of copper, a common ingredient in algacides used during this period The trace metals aluminum, barium, boron, iron, and strontium were detected in borrow pit samples but at concentrations well below water quality standards for protection of aquatic life and drinking water standards for protection of human health Although mercury was not detected in borrow pit samples analyzed at the EPA contractor laboratory, ultra-sensitive analytical methods used by the EPA-ESD in their sampling program indicate borrow pit concentrations of methyl-mercury ranging from less than 0 000033 to 0 000109 g/L and total mercury ranging from 0 000599 to 0 00173 g/L These concentrations are below the established aquatic life water quality standard of 0 012 g/L and the human health standard of 0 144 g/L

Since mercury is known to bioaccumulate in the food chain, the EPA-ESD collected fish from one borrow pit, no 11, for whole tissue analysis Whole tissue analysis for the collected fish ranged between 0 10 and 0 32 mg/kg, which is below DERM's action level of 0 5 mg/kg and USDA safe consumption levels of 1 5 mg/kg for edible fish portions These results are contained in Attachment C

c) Sediment

Sediment analytical results provided by the EPA-ESD for the four borrow pits sampled are presented in Attachment C The analytical results indicate that no pesticides or volatile organics are present at detectable levels in any of the four borrow pit sediments sampled In addition, a majority of the trace metals analyzed were not detected Measurable concentrations for metals detected were 1 9 to 2 9 mg/kg for lead, 49 to 88 mg/kg for manganese, 730 to 930 mg/kg for strontium, 2,200 to 4,000 mg/kg for iron, 3,600 to 6,400 mg/kg for magnesium, 6,300 to 9,500 mg/kg for aluminum, and 340,000 to 360,000 mg/kg for calcium These concentrations are consistent with sediment levels measured by Hudy and Gregory (1984)

The measured concentrations of aluminum and calcium likely reflect calcareous and siliceous minerals characteristic of the minerals removed from the borrow pits during mining operations Magnesium, iron, strontium, and manganese are metals that form carbonates and would be associated with calcareous mineral deposits The presence of low lead levels in the sediments may also be from its presence as a trace carbonate mineral or possibly from the long-term historical accumulation and deposition from atmospheric anthropogenic sources

2. Canals

Canal stations located in the LB area were sampled during the same periods as the borrow pits Analytical results from the canal station sampling are contained in Attachment B The results are consistent with historical results from DERM's Northwest and West Wellfield Protection Programs

During both rounds of sampling, the canal station results indicated that the waters are alkaline and well buffered, with pH in the 7 3 to 7 7 range The trace metals arsenic, cadmium, lead, mercury, nickel, and zinc were not detected in the canal samples Manganese, chromium, and copper were detected in at least one canal sample, but at concentrations near the analytical detection limit and below aquatic life water quality and drinking water standards Iron was detected in all canal samples at concentrations in the range 0 2 to 0 6 mg/L However, iron is not toxic to aquatic life at these concentrations and is only of secondary concern in drinking water because of a taste and odor Ammonia nitrogen measured in the canals ranged between 0 1 and 0 9 mg/L This approaches the 1 3 mg/L total ammonia concentration that would result in an exceedance of the 0 05 mg/L un-ionized ammonia water quality standard (calculated using a pH of 8 0 and a water temperature of 20 C) Other nitrogen compounds and phosphorous, important nutrients in the eutrophication of surface waters, were detected at levels near or below detection limits. These low values probably resulted in low levels of chlorophyll a (less than 1 mg/m^3) reported for the canal stations

3. Groundwater

Groundwater stations were sampled twice, but only water quality parameters were examined The analytical results from the groundwater sampling are contained in Attachment B As was observed for canal stations, groundwater results are within the range of analytical results provided for the stations by DERM

Groundwater samples in the LB area were alkaline (170 to over 300 mg/L), and well buffered, with pH levels in the 7 1 to 8 1 range These characteristics are typical of waters in contact with limestone materials such as those associated with the Biscayne Aquifer

The trace metals arsenic, mercury, and nickel were not detected in any of the groundwater samples Cadmium and chromium were detected in only a small number of groundwater samples, one sample station for cadmium and three sample stations for chromium The concentrations were near the analytical detection limits (1 g/L for cadmium and 5 g/L for chromium) and less than the human health drinking water standard of 10 g/L and 50 g/L, respectively Copper was detected in greater than 25 percent of the groundwater samples Measured concentrations were up to two times greater than the analytical detection limits of 0 005 mg/L, yet well below the 1 mg/L drinking water standard Lead was also detected in greater than 25 percent of the groundwater samples Measured concentrations were up to approximately 100 g/L, which is twice the 50 g/L human health drinking water standard However, the detected levels of lead in groundwater stations were only found at well locations constructed of black steel casing This suggests that the measured levels may be due to contamination from the lead solder used in the casing rather than representing actual groundwater concentrations Zinc was measured at detectable concentrations in the majority of groundwater samples Zinc concentrations at locations NW4B and NW47A were in excess of 0 5 mg/L, but were well below the 5 mg/L taste and odor drinking water standard Aluminum, iron, and manganese concentrations were detected in all groundwater samples, with concentrations ranging from 0 3 to 0 35 mg/L, 0 3 to greater than 25 mg/L, and 0 02 to 0 14 mg/L, respectively The groundwater concentrations exceeded taste and odor drinking water standards of 0 3 mg/L for iron and 0 05 mg/L for manganese but do not pose a human health concern Ammonia nitrogen measured in the groundwater samples ranged between 0 2 and 1 8 mg/L, which is similar to the concentrations observed in canal waters Nitrate/nitrite measured in the groundwater samples were low, with levels well below 1 mg/L This is less than the human health drinking water standard of 10 mg/L Phosphorous, an important nutrient in surface waters, was detected in over half of the groundwater samples, but only at concentrations near the detection limit of 0 02 mg/L

CONSEQUENCES OF THE LAKE BELT PLAN ON WATER QUALITY

A. INTRODUCTION

Water resources within the Lake Belt (LB) area consist of groundwater, natural wetlands, and two types of man-made surface waters borrow pits and canals, which are depicted schematically in Figure 1 Underlying the LB area and surrounding areas is the Biscayne Aquifer, the primary source of drinking water for the Metro-Dade County area The Biscayne Aquifer is a surficial aquifer, which starts beneath the overlying wetland soils and extends to a depth of approximately 100 feet The aquifer is composed of varying limestone-bearing materials such as shells, coral, and sand Borrow pits are the man-made lakes created by the extraction of limestone, the excavated cavity then fills with water from the surrounding aquifer Originally, canals were constructed to convey stormwater from low-lying areas to coastal waters, thereby reducing frequent flooding in large areas of South Florida More recently, SFWMD has used canals to redistribute water resources throughout South Florida for groundwater recharge and Everglades protection (i e , conveying water to and from conservation areas and Lake Okeechobee)

To assist in evaluating water quality impacts of the proposed "Lake Belt Plan," we examined existing water quality information from a variety of sources, including local and state water quality monitoring programs, government reports and documents, resource assessment reports, and scientific publications A comprehensive report on the review of this information is provided in the above sections

B. ASSESSMENT OF FACTORS AFFECTING WATER QUALITY IN THE LAKE BELT AREA

The LB Water Quality Inventory provided characterization of existing borrow pit, groundwater, and canal water quality The inventory was also developed to assess and identify factors that may affect water quality in the borrow pits, groundwater, and canals in the LB area

1. Borrow Pit Water Quality

The Water Quality Inventory sampling program included ten borrow pits selected to evaluate the relationship of borrow pit water quality to the following factors geographical distribution, borrow pit morphology, land use, and mining and reclamation practices The analysis is limited to the parameters that were detected at quantifiable concentrations in the borrow pits Many of the parameters, such as trace metals, were not detected, or were detected at levels near the detection limits in all the borrow pits

a. Geographical Distribution

In order to provide water quality data over the entire area of the proposed LB Plan, borrow pits covering the geographic boundaries, east-to-west and north-to-south, of the LB area were monitored These data were analyzed to determine whether any geographic distribution in the water quality of borrow pits exists Because the monitoring program did not identify any exceedance of aquatic life or drinking water quality standards, there is no basis for linking geography to borrow pit water quality as measured by these standards With one exception, no north to south or east to west pattern was identified for the parameters examined alkalinity, pH, calcium, nitrate, magnesium, potassium, strontium, sulfate, and total organic carbon Sodium concentrations demonstrated a slight decreasing trend in a north-to-south direction

The lack of a geographical pattern in borrow pit water quality is supported by studies evaluating groundwater quality in the Biscayne Aquifer Radell and Katz (1991) found no distinct geographical pattern in either its trace metal or major ion chemistry Any differences in trace metals and major ions in the Biscayne Aquifer were attributed to localized contamination, proximity to canals, overlying wetlands, variability in the geologic formations, and well construction material Mapping of the geologic formations in Dade County indicates that the lithology in the LB area may vary considerably (Causaras 1987) Surface layers in the area consist of Miami Oolite, an oolitic and bryozoan limestone, and vary in depth from 10 to 30 feet Underlying strata consists of the Fort Thompson and Anastasia Formations They are quite variable in composition, containing fresh and marine shelly and nodular limestones, sands, and rock fragments It is likely that the irregular nature of the geologic formations contributes to the lack of geographic regularity in the water quality observed in the borrow pits

b. Effects of Pit Morphology

Borrow pit size and depth were also examined to determine whether these two factors bore any relationship to borrow pit water quality No relationship was detected between size or depth and water quality to a degree that would cause an exceedance of water quality standards In addition, borrow pit size had no effect on general water quality in the borrow pits Increased borrow pit depth was associated with slight increases (less than 10 mg/L) in sodium and chloride levels This is consistent with the findings of Radell and Klatz (1991), who observed significantly higher sodium and total dissolved solids concentrations at greater depths in monitoring wells located in the Biscayne Aquifer The elevated concentrations were attributed to older groundwater from deeper layers of the aquifer, contribution of connate waters from marine deposits, and leakage from underlying brackish aquifers

Depth profile sampling conducted in the borrow pits during the April/May 1995 and February 1996 sampling did not indicate any relationship between borrow pit morphology and water quality While dissolved oxygen concentrations decreased with depth in all borrow pits sampled during the 1995 sampling, no effect of borrow pit depth or size on minimum dissolved oxygen concentrations could be identified Similar to dissolved oxygen, increases observed in maximum conductivity and changes in conductivity below the thermoclines did not appear to have any relationship to the depth or size of the borrow pits

c. Effects of Land Use

Borrow pits were located in, and adjacent to, all land uses represented in the LB This included agriculture, rangeland, roadways, canals, and wetlands containing varying degrees of melaleuca invasion In addition, one monitored borrow pit, borrow pit no 11 (Figure 2), lies outside the LB in an area of predominately urban land use This borrow pit is also in close proximity to the resource recovery facility, a suspected source of groundwater contamination, and the 58th Street Landfill, a known source of groundwater contamination

None of the land uses examined were found to bear a relationship to water quality in the borrow pits This result even holds true for borrow pit no 11, which is located in close proximity to sources of environmental contamination General water quality parameters, including nutrients, did not indicate any differences in water quality as a result of surrounding land use Similarly, sediment sampling, conducted on four borrow pits, also failed to suggest any relationship between land use and borrow pit water quality The sediment samples did not contain detectable levels of volatile organics, pesticides, or the majority of trace metals

d. Effects of Mining & Reclamation Practices

To evaluate the effects of mining practices, water quality of borrow pits excavated by six different mining companies was examined Since no water quality standard was exceeded in the borrow pits sampled, no particular mining practice appeared to immediately contribute to water quality degradation In addition, no differences in general water quality could be attributed to the various mining companies

The standard reclamation practice in the LB area is to construct a littoral shelf around the excavated pit The sampling program included only one pit that did not have a littoral shelf Because of its location in an upland area, this pit did not require a littoral shelf as wetland mitigation No differences in water quality existed between this borrow pit and the other nine pits included in the sampling program Based on this small sample, no water quality benefits appear to result from the current reclamation methods However, since no water quality standards were identified that are currently exceeded in the borrow pits, it is difficult to assess water quality benefit vis-a-vis reclamation method

2. Comparison of Borrow Pit to Canal and Groundwater Quality

The average values for a number of water quality parameters for canals, borrow pits, and groundwater samples, and individual sample results for all parameters are presented in Attachment B The following discussion highlights some notable water quality parameters for which borrow pit measures contrasted with canal and groundwater measures

Drinking Water Standards

Many canal and groundwater station samples exceeded the 1 mg/L drinking water standard for iron None of the borrow pit samples exceeded the iron standard The drinking water standard for manganese was exceeded in some of the groundwater samples, but not in any canal or borrow pit samples The iron and manganese standards exceeded are only secondary taste and odor standards Lead was the only other drinking water standard exceeded in some groundwater samples However, these exceedances are probably attributed to the well casings

Aquatic Water Quality Standards

The ammonia nitrogen concentrations in canal water and groundwater approached the aquatic un-ionized ammonia water quality standard In contrast, the borrow pit ammonia concentrations were measured at or less than detection limits, well below the aquatic water quality standard

Results of zinc testing suggest that bio-geochemical processes in borrow pits may be removing any zinc present in influent groundwater Zinc was detected in many groundwater wells and in several borrow pit samples, but not in any canal samples Two groundwater stations measured zinc concentrations at levels greater than the 0 5 mg/L aquatic water quality standard for surface waters The two borrow pits proximate to these wells did not yield detectable levels of zinc

Phosphorus, an important nutrient in surface waters, was detected in one half of the groundwater samples, but only at concentrations near the detection limit of 0 02 mg/L In contrast, phosphorus was detected in only two borrow pit samples and in none of the canal samples

General Water Quality Measures

Alkalinity, calcium, magnesium, and potassium levels in borrow pit samples measured lower than canals and groundwater The lower borrow pit alkalinities are attributed primarily to the lower concentrations of base cations such as calcium and magnesium These lower base cation concentrations may be due, in part, to carbonate precipitation in the borrow pits

Total organic carbon was lower in borrow pit samples than in canal and groundwater samples Paired comparison of borrow pits and proximate canals found total organic carbon as much as 10 mg/L lower in borrow pits than corresponding canal stations Similarly, paired comparison of borrow pits and groundwater found total organic carbon more than 10 mg/L lower in borrow pits than in proximate groundwater stations The lower borrow pit levels may be a result of chemical and bacterial oxidation of the organic substances in the water and/or a result of absorption of carbonate and oxide precipitates

Nitrates measured considerably higher in borrow pits than in canals and groundwater These higher nitrate levels along with the absence of ammonia, suggest that nitrification of ammonia is occurring in the borrow pits

PH levels of borrow pit samples were higher than groundwater and canal samples The higher pH measurements probably result from aeration of the large open water areas of the borrow pits, which would remove carbon dioxide, thereby increasing pH

3. Impacts of Limnological Processes on Borrow Pit Water Quality

No aquatic water quality standards or drinking water standards were violated in any of the borrow pits sampled However, several parameters in surrounding canal and groundwater in the LB area were identified that could lead to violation of aquatic water quality standards in the borrow pits In addition, depth profile results collected from the borrow pits indicate that limnological processes may potentially impact water quality during periods other than the late winter and spring seasons when sampling occurred The water quality inventory results also suggest the importance of several limnological processes in the borrow pits that could be providing beneficial effects on borrow pit water quality

High groundwater and canal water ammonia levels were not found in the LB area borrow pits, even though the source of water in the borrow pits would be from groundwater sources Nitrification, the biological oxidation of ammonia to nitrate by bacteria, is common in well-oxygenated surface waters Evidence to support the presence of nitrification in the borrow pits is provided by the absence of ammonia and the presence of nitrite/nitrate in the borrow pits, the latter was not typically detected in groundwater or canal water

High levels (greater than 5 mg/L) of dissolved oxygen were measured in the borrow pits This is in comparison to low- to non-existent levels (typically less than 2 mg/L) measured in canal and groundwater The absence of dissolved oxygen in groundwater is not unexpected since organic soils overlying the groundwater would remove most or all of the dissolved oxygen Low dissolved oxygen measured in the canals is likely an indication of the close association of canal water and groundwater, the poor aeration in the canals is due to the low surface area to depth ratio of the canals In comparison, borrow pits are large open areas that permit improved surface aeration by wind-driven turbulence and mixing Aeration could also be provided by phytoplankton, which release oxygen as an end product of photosynthesis However, chlorophyll *a*, an indicator of phytoplankton productivity, was measured at low levels in the borrow pits, suggesting that this process is not a substantial source of borrow pit dissolved oxygen

Analysis of the depth profile results for the borrow pits identified stratification, a potential water quality concern The April/May 1995 sampling indicated that the borrow pits may develop thermocline, a stratification of water temperatures This could result in isolation of the deeper waters ("hypolimnion") from the surface layers ("epilimnion") The lower dissolved oxygen levels measured in the deeper waters during the April/May 1995 sampling are evidence of stratification Seasonal thermal stratification, maintained throughout the summer period, could deplete dissolved oxygen levels in the hypolimnion, thereby eliminating deep water habitat for most aquatic life Thermal stratification and the resulting depletion of oxygen in the hypolimnion occurs in many natural lakes and is not unique to the LB area or the excavated limestone borrow pits Dissolved oxygen levels in the epilimnion typically remain near saturation due to aeration and photosynthesis, thereby providing a sufficient habitat for aquatic life

An additional concern of the stratification and the resulting absence of oxygen is the development of anaerobic processes within the hypolimnion and deep sediments Ammonification of nitrate is an anaerobic process that increases ammonia levels Reduction of mineral oxides is an anaerobic process that can release trace metals from sediments Reduction of sulfate into toxic sulfides is another process that can occur in the absence of oxygen However, under existing borrow pit water quality conditions (low levels of nitrate, trace metals, and sulfate), the potential for these anaerobic processes is not a great concern

An important process in maintaining the water quality in the borrow pits is associated with the high alkalinity and calcium concentrations that result from the solubilization of limestone contained in the minerals of the surrounding Biscayne Aquifer As noted previously, both groundwater and canal water samples contained higher alkalinities (greater than 50 mg/L) than the borrow pits sampled Higher alkalinities in the groundwater result indirectly from the elevated carbon dioxide levels produced by decomposition processes in overlying organic soils With aquifer carbon dioxide levels greater than atmospheric levels, the solubility of the limestone is increased When the groundwater is exposed to the atmosphere in the borrow pit, carbon dioxide is released to the atmosphere The water becomes supersaturated with respect to carbonates and calcite precipitates out of the water column, thereby lowering calcium and alkalinity Photosynthesis by phytoplankton, which removes carbon dioxide from the water, could further enhance calcite precipitation in the borrow pits

The lower pH measured in ground/canal waters, than in the borrow pits, provides evidence of carbon dioxide release This is true even though ground/canal waters are more alkaline However, high borrow pit concentrations of sediment calcium indicate the presence of calcite Because of the kind of sediment analysis conducted, it is not possible to differentiate between precipitated calcite and the calcite contained in the underlying sediments Calcite precipitation in the water column may be an important process in removing nutrients, metals, organic carbon, and other suspended solids This is due to the formation of suspended solids that scavenge these materials upon settling The comparatively lower levels of iron, manganese, zinc, phosphorus, and total organic carbon in borrow pits suggest the process is occurring

C. POTENTIAL WATER QUALITY IMPACTS OF THE LAKE BELT PLAN

The excavation of mineral deposits pursuant to LB construction would convert a large portion of the Biscayne Aquifer to surface waters These alterations could result in significant changes to water quality in the LB area This in turn could negatively impact aquatic life that may reside in the created open water and could endanger drinking water supplies for the Metro-Dade area

1. Aquatic Life Resources

Monitoring in the LB area found existing water quality in the borrow pits to be in compliance with ambient water quality standards Hence, existing aquatic life will not be adversely impacted In addition, analysis of the monitoring program did not identify any factors, such as borrow pit morphology, mining, or reclamation practices, which would cause an adverse water quality impact in the proposed LB This is providing that no alterations to source water occurs However, changes in source water to the borrow pits could produce water in the LB that exceeds ambient water quality standards for several parameters Current water quality in borrow pits in the LB area is linked to a groundwater geochemical and borrow pit limnological processes This produces water chemistry that leads to calcite precipitation within the borrow pits As noted previously, water quality could be degraded by additional input of pollutants from point and nonpoint source runoff The impact of these two factors on water quality in the proposed LB is discussed below

a. Changes in Groundwater Inputs

The Water Quality Inventory identified a limnological process dependent on the high alkalinity and calcium content of the Biscayne Aquifer This is important in maintaining borrow pit water quality and future water quality of the proposed LB As discussed, the high alkalinity and calcium concentrations result in precipitation of calcite in the borrow pit Calcite precipitation and accumulation in bottom sediments has also been documented in naturally occurring "marl" lakes, i e , those receiving groundwater inputs from calcareous aquifers (Brown, *et al* 1992 and Duston *et al* 1978) The calcite precipitate would form suspended solids, which would scavenge trace metals, nutrients, organic carbon, and other suspended solids (e g , phytoplankton) upon settling from the water column to the bottom sediments

The beneficial effects of the calcite precipitation process in maintaining water quality are provided in a study by Burney and Forman (1991) The investigators evaluated water quality in a rock pit that received effluent from a wastewater treatment plant for 20 years When this type of effluent is discharged to surface waters, it can decrease dissolved oxygen and enhance eutrophic conditions, however, the investigators found the effluent to have no impact on the rock pit water quality The investigators attributed the water quality maintenance in the rock pit to the continual removal of nutrients, organics, and trace metals from the water column by calcite precipitation The effect of nutrient removal, particularly phosphorous in the form of calcium phosphate minerals (e g , apatite), was also observed in marl lakes that were artificially supplemented with excess fertilizer (Hooper and Ball 1964) The fertilizer applications were found to be ineffective at increasing lake productivity, which Hooper and Ball attributed to phosphorous precipitation to the bottom sediments The absence of measurable phosphorous in the borrow pits in comparison to groundwater and canal water samples may also provide evidence that calcite precipitation removes phosphorous The result of this is the low productivity of the borrow pits, as indicated by the low chlorophyll *a*.

The LB Water Quality Inventory results indicated a gradient effect, with the eastern borrow pits containing lower alkalinity and calcium than the adjacent western borrow pits Since groundwater flow is likely to be from west to east in the area, the results may reflect water movement from the westerly borrow pit, in which calcite precipitation has occurred, to the easterly borrow pit, resulting in the lower alkalinity and calcium concentrations This may result in lower calcite precipitation and lower water quality remediation potential in the easterly borrow pits In a large open water system, as in the proposed LB, groundwater will continue to supply water to the western edge of the proposed LB However, due to distances across the LB and barriers left in place from historic mining, mixing of waters may be limited and lower alkalinities and calcium concentrations, well below saturation, in eastern portions of the LB may occur Maintenance of a west to east groundwater flow gradient through the remaining Biscayne Aquifer and adequate mixing within the proposed LB will be essential for maintaining the calcite precipitation process This process is required for long-term compliance with ambient water quality standards of the proposed LB

b. Pollutant Inputs

Literature indicates that the water quality of borrow pits can be degraded as a result of surrounding land use, for instance, the input of excessive nutrients Jackson and Maurrasse (1976a and 1976b) found that both rock-mined pits and real estate lake water exhibited cultural eutrophication because of excessive nutrient inputs from residential nonpoint runoff and point source discharges This cultural eutrophication resulted in excessive algal growth, forming aesthetically displeasing algal mats and odors Adverse water quality impacts included depletion of oxygen, even at shallow depths, together with elevation of ammonia and sulfides In a more recent study, Hudy and Gregory (1984) found that borrow pits located in urban areas may be impacted by eutrophication, which could deplete dissolved oxygen in the hypolimnion of the lakes

Supporting evidence of lake contamination from urbanization is provided by Weinberg *et al* (1980) The investigator reported elevated levels of several contaminants, including chloride, total kjeldahl nitrogen (TKN), and chemical oxygen demand (COD), in a lake receiving runoff from a high-density residential area Beaven and McPherson (1978) examined borrow pits in the vicinity of a highway They found elevated levels of chromium in water samples and lead in sediments relative to borrow pits in mostly undisturbed areas Contamination of borrow pits from urban runoff is possible Studies by Miller *et al* (1979) and Mattraw and Miller (1981) indicate that runoff from a variety of land uses in South Florida—including residential, commercial, and highway—contains elevated nutrients, trace metals, COD, dissolved solids, and indicator bacteria

Stability of water quality in the borrow pits is a function of the limited amount of development in the LB area Agricultural activities adjacent to borrow pits were not found to alter borrow pit water quality This is probably a result of embankments left during excavation, hence there is limited direct runoff to the borrow pits Urbanization may remove these barriers and cause surface runoff to be directed into the borrow pits, thereby eliminating the remediation provided by groundwater infiltration This would suggest that land use planning adjacent to the LB, coupled with runoff control measures, will be necessary to prevent excessive nutrients/contaminants from entering the proposed LB

2. Drinking Water Supply

The borrow pit monitoring in the LB area also found existing water quality to be in compliance with drinking water standards This indicates that water quality in the borrow pits in the LB area is adequate as a public water supply In fact, a number of parameters were lower in the borrow pits than surrounding groundwater (e g , iron, manganese, and TOC) This suggests that an increase of open water may be beneficial to the water supply Lowering iron and manganese will improve the aesthetic quality (taste and odor) of the water and reduce the amount of chemical treatment required and sludges produced TOC reduction will reduce the amount of chlorinated hydrocarbons, a byproduct of chlorination This may reduce the health risk of the water supply to the public

Analysis of the monitoring program results did not identify any factors, such as borrow pit morphology, mining/reclamation practices, or proximity to canals that would cause an exceedance of drinking water standards However, if alterations to source water occur, such as input of point source discharges and non-point source runoff (via canals), exceedance of drinking water standards for several parameters may result

Current water quality in borrow pits in the LB area is linked to limnological processes in the borrow pits and geochemical processes in the source groundwater Future water quality is likely to continue to be greatly influenced by these same processes as well as changes in the surrounding area that result in additional input of pollutants from point and non-point source runoff The impacts of these two factors on water quality in the proposed LB were previously discussed

In addition to factors affecting chemical contamination, concerns regarding waterborne disease in the LB must also be considered and evaluated This is especially true with respect to the potential impact(s) on the Northwest and West Wellfield public water supplies Waterborne disease is a general term that encompasses gastroenteritis, shigellosis, cholera, and dysentery These gastrointestinal maladies are caused by a variety of microorganisms present in human as well as other warm-blooded animal fecal matter In North America, outbreaks of waterborne disease are uncommon due to treatment and disinfection of our wastewater and chlorination of our drinking water supplies Nonetheless, recent outbreaks of waterborne disease in the United States have occurred, they were caused by microorganisms resistant to disinfection processes Protection of drinking water supplies from these microorganisms is accomplished by routine filtration All surface water authorities in the United States are required to provide filtration However, since Northwest and West Wellfields are groundwater supplies, they are excluded from this requirement

Increasing surface water areas adjacent to the Northwest and West Wellfields by limestone excavation may affect the residence time of water in the wellfields This in turn could potentially reduce the natural filtration properties provided by the groundwater systems It must be noted that the high permeability characteristics (i e , solution cavities, channels, and conduits in the limestone) of the Biscayne Aquifer, the extensive historic mining in the vicinity of the wellfields, and the close proximity of canals to the wellfields make it probable that the effectiveness of the natural filtration processes is already compromised

Currently, disease-related microbial contamination in the LB is minimal This is due to the absence of significant human activity within and adjacent to existing borrow pits and the absence of wastewater treatment plant effluent discharges to any borrow pits or adjacent canals In addition, the unique properties of the water chemistry (i e , calcite precipitation) in the borrow pits likely provide for the transformation of suspended microorganisms to bottom sediments, where their viability is naturally eliminated It is expected that the proposed LB will be minimally impacted by human-related contamination as long as land use remains unchanged in areas surrounding the LB, and the LB does not receive any point source wastewater effluent or non-point source urban runoff, via canals, which can contain exceedingly high levels of microorganisms (Mattraw and Miller 1981) Additionally, high-impact recreational activities, such as public bathing and pleasure boating, also have the potential to be a significant source of microbial contamination

D. RECOMMENDED MITIGATION MEASURES

No existing water quality related impacts of mining in the LB area were identified by the LB inventory However, the following potential consequences of the proposed LB plan were identified

- Poor west to east mixing will lower alkalinity and calcium concentrations in eastern areas of the LB as a result of calcite precipitation

- Changes from existing agricultural and wetland land uses to more urbanized land use in the vicinity of the LB may add pollutant imputs

- Input of waters, such as treated and untreated wastewater and/or stormwater runoff via canals to the LB, may reduce water quality

- High-impact recreational activities may result in greater potential for microbial contamination of the LB waters

The two noted public water supply wellfields provide the Metro-Dade populace with the majority of its public drinking water Thus, protecting water quality in the LB area is imperative Mitigation measures to provide the level of protection necessary for the long-term use protection of the wellfields can be separated into two categories First, are measures associated with the mining and reclamation practices, which will enhance mixing within the LB, minimizing unwanted water inputs into the LB The recommendations include

- Removal of existing barriers between borrow pits by dredging to a minimum of 15 feet of water depth

- Removal of any existing direct canal connections to borrow pits, and maintenance of a minimum 100-foot distance between canals and the LB

- Construction of a berm around the LB to prevent direct entry of surface water runoff

Secondly, measures related to land use can be cumulatively combined under the heading of a Lake Belt Management Plan The plan should include measures to protect the LB from activities that may jeopardize future water quality through chemical and microbial contamination Measures could include

- A watershed protection plan to protect/prevent future development of the western wetland conservation areas from any future land development This would include prohibiting limestone excavation in an effort to maintain input of the highly alkaline groundwater to LB

- A land use protection plan to prevent future urbanization of the areas surrounding the LB primarily to the east This would prevent and minimize input of urban runoff

- A recreation plan that would focus on activities that would lessen excessive chemical and microbial contamination of the LB

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